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CONDENSATION AND PRECIPITATION IN THE ATMOSPHERE

By F. J. Scrase, Sc.D., F. Inst. P.

Until comparatively recent years it was thought that the process of condensation and precipitation of water from the atmosphere was a simple and straightforward one. The water was supposed to remain entirely in the vapour form until the relative humidity reached 100 per cent., after which it condensed into a visible cloud of liquid droplets. It was thought that in favourable conditions the process would continue until the droplets became large enough to fall as rain. These ideas fall far short of the true representation of the facts; it is now known, for example, that condensation can commence at humidities well below 100 per cent. and that precipitation, although it naturally follows condensation, is not merely a continuation of the same process on a more intense scale.

A factor which plays a vital part in the process of condensation in the atmosphere is the presence of hygroscopic nuclei; these consist chiefly of salt particles produced by sea spray and of certain products of combustion such as nitrous and sulphuric acids. In the complete absence of nuclei, condensation cannot

take place except with a very high degree of supersaturation (equivalent to a relative humidity of more than 300 per cent.). Owing to their hygroscopic nature, condensation nuclei are able to grow by absorbing water vapour even though the humidity may be as low as 80 per cent. In unsaturated air, however, the rate of growth of nuclei with increase in humidity is small, for although there is a reduction of vapour pressure due to the fact that the growing nucleus is a solution instead of pure water this decrease is opposed by an increase of vapour pressure due to the curvature of the surface of the particle. As the relative humidity approaches the saturation value the rate of growth increases; for each size of nucleus (the initial radius usually lies between 10^{-5} and 10^{-6} cm.) there is a critical humidity, higher than 100 per cent., at which further growth can occur without any further increase in humidity. When this stage is reached there is a rapid growth to the visible droplets, with radii lying between 10^{-3} and 10^{-4} cm., which constitute cloud or fog. The critical humidity for rapid growth depends on the size and nature of the nucleus; for the smaller and less hygroscopic nuclei the critical value may be as high as 110 per cent., whilst for the larger and more hygroscopic nuclei it is between 100 and 101 per cent. On this account only a portion of the nuclei present in the air may grow into cloud or fog droplets, for the rapid growth of the larger nuclei tends to prevent the humidity from increasing to the higher critical values that are necessary for rapid growth of the smaller ones. This explains why the number of droplets per unit volume in a cloud or fog is usually very much smaller than the number of nuclei. The rapid growth of droplets when slight supersaturation is reached also explains why the base of a cloud is often sharply defined.

The size which cloud droplets ultimately attain by condensation is limited by the amount of water vapour available; after the critical humidity for the larger nuclei is reached the rate of increase in humidity is checked and there is no further increase when the amount of vapour condensing on the droplets is equal to the amount

supplied to the air. If the number of larger nuclei is relatively small, or if the rate of supply of water vapour is high, the condensation on the larger nuclei may be insufficient to check the increase in humidity, in which case the critical values for smaller nuclei will be reached and more nuclei will take part in rapid condensation. Thus it is found that in fogs, where the rate of cooling is small and the relative humidity seldom exceeds saturation value by more than 1 per cent., there are fewer droplets than in convexion clouds in which the rate of cooling is rapid and in which higher degrees of supersaturation are known to occur. Measurements indicate that the amount of suspended water in clouds is never likely to exceed 10 gm./$m.^3$ and if we take the minimum number of droplets in a cloud to be 20 per c.c. (the average number is more of the order of 200 per c.c.) then we find that the maximum radius which cloud droplets can attain by condensation is 3×10^{-3} cm. The limiting velocity of fall of droplets of this size is only 10 cm./sec. and such droplets would evaporate long before reaching the ground. Drops falling from a cloud at a height of 1 km. must have an initial radius at least three times as great (or a volume 30 times as great) as that of the largest cloud droplets in order that they can reach the ground without evaporating completely. It would seem that the only occasions when precipitation is caused solely by direct condensation are those when drizzle falls from fog or low-lying cloud. How, then, are we to account for the formation of raindrops of the sizes that usually occur in moderate and heavy rain? For it is clear that when the growth of droplets by condensation ceases some other process or processes must operate to cause either the coalescence of the small cloud particles into raindrops or the growth of some of the cloud elements at the expense of others.

The idea of coalescence of droplets has received much support from those who consider that clouds and fogs may be regarded as colloidal suspensions of water in the air. The colloidal state is one in which the movement of particles suspended in a medium is governed by

molecular bombardment rather than by gravity and colloidal solutions have the property of persisting with their particles unchanged until a condition occurs that causes coagulation and precipitation of the particles. It was argued that in the case of clouds and fogs coalescence takes place only with drops of equal size, which can remain near together long enough for hydrodynamical attraction to act. A more likely cause of coalescence is the difference in size of the droplets, the larger ones falling relatively to the smaller ones and absorbing those with which they collide. It seems fairly certain that the electrical state of the droplets has some effect on the stability of fogs, for the electric repulsion between droplets carrying high charges of like sign may be sufficient to prevent their coalescence; on the other hand it is not likely that the attraction between droplets carrying charges of opposite sign is sufficient, by itself, to cause coalescence. Although it is probable that coalescence of droplets does occur in natural clouds and fogs and may in some circumstances be responsible for light rain, there appears to be no very clear evidence that it is the main mechanism in the production of precipitation in general.

In recent years the idea has gained ground that the essential factor in the production of precipitation of at least moderate intensity is the co-existence of water in the solid and liquid states; in other words there must be ice crystals present in the clouds in addition to water droplets. This, of course, means that the temperature in some parts of the cloud must be below the freezing point and since it is a well known fact that water droplets can undergo a high degree of super-cooling before solidifying, it is certainly possible for the ice and water phases to occur together. The extent of the super-cooling probably depends on the size of the droplets, the smaller droplets being more likely to remain in the liquid state at lower temperatures. We may say that as a general rule water droplets predominate in the layers of cloud which are at temperatures above $-10°$ C; in the layers with temperatures between $-10°$ C to $-20°$ C there is a

mixture of both ice crystals and water droplets, whilst ice crystals predominate where the temperature is below $-20°$ C. It is in the region where ice crystals and droplets exist together that we can expect precipitation to originate, for since the saturation pressure over ice is less than that over water there is a strong tendency for the water vapour present in the air to sublime (i.e. to pass directly from the vapour state to the solid state) on the ice crystals and for the droplets to evaporate. The ice crystals are thus able to grow at the expense of the droplets and eventually they become large enough to sink. It is probable that they then continue to grow by collision and coalescence with each other and with droplets that they meet in falling; if the temperature in the lower layers is sufficiently high the crystals will turn to rain before reaching the ground. In brief, the theory is that all precipitation of appreciable intensity starts as snow.

As to the origin of ice crystals in clouds that consist initially of super-cooled drops, it has been suggested that in addition to nuclei of condensation there are nuclei of sublimation (possibly very fine dust or sand-grains) on which ice crystals will form when the temperature is sufficiently low for the vapour pressure in the air to be greater than that over an ice surface. Whether such nuclei exist or not at cloud levels remains to be confirmed. It is possible that some ice crystals are formed in water clouds when super-cooled drops collide with each other, for it is well known that disturbance of super-cooled water can cause immediate crystallisation. High clouds are, we know, composed of ice crystals and some of these crystals may be carried into a lower-lying water cloud by gravitational settling or turbulent mixing. The co-existence of the ice and water (and vapour) phases is, at any rate, physically possible and it affords a reasonable explanation as to how precipitation can take place after the process of condensation ceases to produce further growth of cloud elements. It also explains the persistence of low clouds that do not produce any appreciable rain; such clouds must be devoid of ice

crystals either because they are below the level of the freezing point isotherm or, if they are above this level, because their super-cooled droplets remain in the liquid state on account of their uniform size and freedom from disturbance by collision; absence of nuclei of sublimation would also account for the absence of ice crystals.

The Levanter cloud, which is a characteristic feature of Gibraltar*, is a good example of persistent rainless cloud; this cloud, which forms over the Rock and extends over the neighbouring Bay, may persist for days and although on occasions it may look as black and as threatening as a thunder-cloud it is very rarely that any appreciable rain falls from the cloud itself, presumably because the temperature in the cloud is never low enough for ice formation. When rain does occur during Levanter conditions there is usually higher cloud present as well.

One of the objections that is often raised against the idea that the presence of ice is necessary for appreciable precipitation is that heavy tropical rains are observed to fall from clouds in which the temperature must everywhere be above freezing point. Such cases are rarely supported by concrete evidence as to the temperature at all levels in the clouds and as to whether higher layers of cloud are present.

The problems connected with the co-existence of the ice, water and vapour phases in the atmosphere are of importance not only in connexion with the formation of precipitation, but also with the phenomenon of ice accretion on aircraft and it is to be hoped that the solution of these problems will not only be of assistance in the forecasting of precipitation but will help to overcome what still remains one of the greatest dangers to aviation.

* A photograph of a typical Levanter cloud is reproduced in the April 1935 issue of this Magazine.

SOME VARIATIONS OF TEMPERATURE

By A. C. Best, M.Sc.

Air temperatures as high as 136° F. and as low as - 94° F. have been measured in the thin layer of the atmosphere in which we normally live. The former occurred in Tripoli (*Meteor. Mag.*, 1926, p. 157) and the latter at Verkhoyansk in Siberia (*Meteor. Mag.*, 1926, p. 158). Between these two extremes many variations occur and if the temperature of the surface of the earth is also considered, even higher temperatures have been measured under natural conditions. It is proposed to discuss some of the more extreme variations of temperature which are on record.

The temperature with which we are most familiar is that usually known as the " shade temperature ". This is the temperature of the air at a height of about four feet above the earth. It varies from hour to hour, from month to month and from place to place. Even simultaneous measurements made within fifty feet of each other may differ by one or two degrees. The height at which the shade temperature is normally measured is mentioned above because large differences of temperature frequently exist between different heights at the same place, even if consideration is limited to the first fifty feet above the surface of the earth.

While considering all these variations one point should be borne in mind, viz. that one of the main factors affecting the temperature of the air is the temperature of the surface of the earth, since the air absorbs but little of the radiation of the sun. The earth, however, absorbs heat from the sun more or less readily, depending on the nature of the surface, and in turn warms the air by day and cools it by night. This heating and cooling spreads upwards from the surface.

Thus we are led to consider the temperature attained by the earth's surface as a starting point. This will depend upon the nature and the colour of the surface. Some experiments carried out on Salisbury Plain* (1, Johnson and Davies, 1927) indicate that in summer in England a tarmac surface may attain a temperature of about 140° F. and a sand or earth surface may reach a maximum temperature of about 10° F. lower. The corresponding air temperature at a height of four feet would be about 75° to 80° F. In winter the difference between air and surface maximum temperatures amounts to a few degrees only. Some figures for Egypt (2, Ministry of Public Works, Egypt) show that the average surface temperature of a locomotive rail and of a stone roof between 1 p.m. and 2 p.m. in summer are about 130° F., the surface temperature of limestone rock being some 14° F. lower. In winter the three surfaces are very similar with a temperature of about 80° F. at 1.30 p.m., some 12° to 13° F. above the air temperature. These figures for Egypt are average figures and to compare with the figure of 140° F. mentioned above for England we may consider the occasion when the temperature of some undisturbed fallow land at Giza was found to reach a value of 150° F. In India a temperature of 156° F. has been recorded for the surface of the soil (3, Shaw, p. 54) and in the Sahara a value of 172° F. has been attained. The highest value the temperature of any surface is likely to reach anywhere in the world is a matter for speculation. In this connection it is of interest to note that the average daily maximum temperature as indicated by a special type of thermometer called the "Absolute Black Bulb" thermometer at Aswan (in Egypt) for the four months May to August is just over 176° F. This thermometer is designed to absorb as much radiation from the sun as possible and to lose the minimum amount of heat by conduction, etc. Thus we may reasonable assume that the reading of an absolute black bulb thermometer represents the highest

* The numbers refer to the list of references at the end.

temperature that any type of surface can attain under similar conditions. The figure 176° F. is the average daily maximum over four months. The writer has not found any published figures giving the highest temperature reached by this thermometer on any one day, but there seems little doubt that it must sometimes exceed 180° F. in Egypt. [In the Karakoram Mountains a value of 204° F. has been attained at a height of 17,322 ft. (*Meteor. Mag.*, 1926, p. 213).] Bearing in mind the fact that a sand surface temperature has been measured in Arizona which was 11° F. higher than the highest earth surface temperature measured in Egypt, it seems probable that the highest temperature likely to be attained by any surface at any time and at any place is between 190° and 200° F.

Having seen how hot the surface of the earth can be let us now turn to the other side of the question and consider the lower limits of temperature. The available figures are not nearly so impressive. In the Salisbury Plain experiments referred to above it was found that the minimum surface temperature differed very little from the minimum air temperature at a height of four feet. This is supported by observations from other parts of the world; at Giza, for example, the normal reading of the grass minimum thermometer is only a few degrees below that of the air thermometer. On occasions, however, even in England the reading of the grass minimum thermometer may be 10° to 15° F. below the reading of the screen minimum thermometer. The only reference to really notably low surface temperatures which the writer has encountered is contained in the statement (3, Shaw, p. 54) that frosts are sometimes experienced in the desert at night even during summer months.

Since surface temperatures attain values much higher than air temperatures it is clear that under suitable conditions there must be considerable variation in the temperature of the air at different heights even when only small heights, say up to 50 feet above the surface, are considered. Some experiments carried out over

close-cropped grass on Salisbury Plain (4 and 5, Johnson, 1929, and Best, 1935) provide the data for considering the variations likely to occur in England. These experiments were concerned with the temperature differences between the heights 1 inch, 1 foot, 4 feet, 23 feet and 56 feet above the surface. It was shown that temperature generally decreases upwards during the daytime and increases upwards at night, the changes from one type of variation to the other occurring just after sunrise and just before sunset. The rate of increase upwards at night showed little variation either during the night or from month to month. The rate of decrease upwards during the daytime however increases to a maximum round about noon and this maximum value increases in turn from winter to summer. As would be expected the greatest rates of increase or decrease occurred in the lowest layers. The largest temperature differences recorded were 9·7° F. between 1 inch and 1 foot, 4·6° F. between 1 foot and 4 feet, 3·8° F. from 4 feet to 23 feet and 4·6° F. from 4 feet 56 feet. Although these maximum values were not recorded simultaneously they do indicate the possibility that the air temperature 1 inch above closs cropped grass may be nearly 20° F. higher than the air temperature at a height of 56 feet. Over a black surface (e.g. tarmac) the difference might be greater still. The greatest temperature differences obtained at night showed an increase of temperature upwards of 7·8° F. from 1 inch to 1 foot, 6·3° F. from 1 foot to 4 feet, 7·0° F. from 4 feet to 23 feet and 10·2° F. from 4 feet to 56 feet. These figures amply explain the greater frequency of ground frosts as compared with occasions when the air temperature (4 feet above the ground) falls to freezing point.

Some similar experiments to those just described have been carried out in Egypt (6, Flower, 1937). Only one comparable height interval was used there, viz. 4 feet to 53 feet. The greatest temperature differences recorded over this layer were 4·7° F. in the daytime and 13·4° F. at night.

One effect of the vertical variation in temperature is found when we examine figures for the diurnal range of temperature. This decreases rapidly from the surface upwards. We have seen that the surface temperature in the desert may vary from 32° F. at night to 172° F. in the day, a range of 140° F. An occasion is on record (7, Kendrew, p. 26) when the air temperature in the Sahara varied from 31°F . to 99° F. in the same day. The diurnal range of temperature is very much influenced by the topography of the neighbourhood. In a valley the maximum and minimum temperatures are likely to be respectively higher and lower than those measured at a more normal site. Some data are available for a valley station at Rickmansworth in England (8, Hawke, 1936). On one occasion there the temperature rose from 34° F. at 0545 G.M.T. to 84·9° F. at 1430 G.M.T., giving a variation of nearly 51° F. in nine hours. Some figures are available for England (5, Best, 1935) which indicate that the average diurnal range on clear summer days on a more normal site may vary from about 32° F. at a height of one inch above grass to about 20° F. at a height of 56 feet. In so far as records are available it appears that the average diurnal range of temperature has a maximum value at Calama (3, Shaw, p. 45) where it reaches 41° F. In contrast to these big changes of temperature during the day we have a diurnal range of only one or two degrees in the temperature of the air over the oceans.

The annual range of temperature is also a matter of considerable interest. At Verkhoyansk (7, Kendrew, p. 176) the mean monthly temperature varies from - 59° F. in January to 60° F. in July, giving a mean yearly range of 119° F. The absolute maximum at this place is 93° F. and the absolute minimum as mentioned above is - 94° F. so that temperatures there have varied over a range of 187° F. For comparison it may be mentioned that the highest and lowest temperatures recorded in the British Isles are 100·5° F. and - 17° F. (9, Bilham, pp. 174, 5).

We saw at the beginning that an air temperature as high as 136° F. has been measured. It is worth noting that temperatures between 120° F. and 130° F. are recorded nearly every year in various parts of the world. Similarly, to compare with the low value of - 90° F., we may remember that temperatures as low as - 75° F. are recorded somewhere nearly every year.

These very high and very low temperatures are measured in regions in which man can live. There are, naturally, no long series of records for the other type of region, but some temperatures measured in the polar regions may be of interest. At the north pole the lowest temperature measured so far is - 33° F. (3, Shaw, p. 45) and in the south polar regions a value of - 76° F. has been recorded on the Ross Barrier (7, Kendrew, p. 384). Still less data are available of the temperatures on Mount Everest but the lowest temperature measured there so far appears to be - 2·2° F. at a height of about 21,000 feet (3, Shaw, p. 45).

In conclusion the writer does not claim that all the extreme values mentioned above are world records; the figures do show, however, what variations in temperature are possible from time to time and from place to place.

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THE RAINFALL AT SHORT HEATH LODGE, FARNHAM, SURREY, 1899–1938, MAINTAINED BY THE LATE COL. GEORGE CHRYSTIE

By A. Hampton Brown

A record of rainfall maintained in the same position for 40 consecutive years is not too common and particulars of the figures for Shortheath, Farnham, for that period may be of interest. Shortheath is one mile south of Farnham, overlooking the town on a ridge of high ground running practically NE and SW. The height of the ground at the rain gauge is 360 ft. and the ridge falls away quickly both to the north and south. The Hampshire border to the north of Farnham is about three miles away with hills reaching the height of 600 ft. To the south and south-east are both Hampshire and Surrey with Hindhead to the south-east about seven miles distant and rising to practically 900 ft. The observations were recorded by Col. G. Chrystie and his gardener and there appear to be no gaps in the readings.

The monthly averages are given in Table I and it will be seen that December is the wettest month with 3·49 in. and June the driest with 2·00 in. The rainfall is markedly of the autumn and early winter type; no less than 42 per cent. of the annual total falling in the four months October to January. After February the amount falls away rapidly and from March to June the monthly average is two inches or a little over. There is no secondary maximum in July such as is found in many records further to the east and usually associated with thunderstorm rains, and there is a local tradition that severe thunderstorms are not common in the district. There is, however, a marked minor minimum in September followed by a sharp rise of over one inch in October, the second wettest month of the year. December is appreciably wetter than October.

TABLE I

Month	Average 40 years			Monthly Extremes			
	Inches	Milli-metres	Rain-days	Greatest		Least	
				in.	date	in.	date
January	2·88	73·1	19	6·77	1937	·62	1914
February	2·34	59·4	15	5·16	1915	·06	1934
March	2·08	52·8	15	4·31	1905	·13	1929
April	2·09	53·1	15	4·36	1907	·05	'12, '38
May	2·05	52·1	14	5·04	1932	·20	1919
June	2·00	50·8	12	5·00	1905	·02	1925
July	2·34	59·4	13	5·80	1918	·29	1921
August	2·44	62·0	14	5·55	1917	·78	1906
September	2·18	55·4	13	5·50	1918	·17	1929
October	3·22	81·8	17	8·80	1903	·57	'21, 31
November	2·94	74·7	16	7·91	1929	·51	1909
December	3·49	88·7	19	9·24	1914	·31	1926
Year	30·05	763·3	182	42·85	1903	14·32	1921

The average number of rainfall days with amounts of ·01 in. or more is 182, December and January having 19 each and June 12.

With the monthly extremes (Table I) the maximum amount is 9·24 in. in December 1914 the next highest being 8·80 in October 1903. These are the only monthly totals in the 40 years exceeding eight inches. There are altogether five months with totals of less than one tenth inch, all occurring between February and June.

Of the daily falls (Table II) the highest outstanding amount is 3·36 in. which fell on July 25th, 1901. This was due to a thunderstorm which must have been very local as Colonel Chrystie states the sun was shining most of the time at the village of Rowledge less than 2 miles to the SW. Other falls of two inches or above occurred in December 1914 and October 1915. During the 40 years, only on three occasions did the annual extreme fail to reach one inch. No month during the period was

TABLE II

Month	Daily Extremes				Days of Rain			
	Greatest		Least		Most		Least	
	in.	date	in.	date		date		date
January	1·71	1908	·21	1914	27	1906	8	1935
February	1·26	1923	·02	1934	25	'16, '23	2	1932
March	1·03	1916	·07	'29, '38	28	1909	3	1929
April	1·05	1919	·04	'12, '38	24	1920	2	'12, '38
May	1·77	1932	·06	1919	25	1902	4	1901
June	1·63	1906	·02	'21, '25	21	'07, '12	1	1925
July	3·36	1901	·09	1921	24	1936	4	1911
August	1·44	1925	·19	1906	26	'02, '12	6	'99, '20, '33, '37
September	1·92	1912	·12	1929	24	1918	2	1929
October	2·09	1915	·18	1921	29	1903	7	'21, '31
November	1·57	1899	·22	'09, '17	26	'03, '26	7	1901
December	2·00	1914	·15	1926	28	'11, '34	6	1932
Year	3·36,	1901 July 25	·02	Feb. '34 June, '21, '25	235	1903	124	1921

entirely rainless but June 1925 received only ·02 in. on one day. Four other months had measurements on two days only but none of these occurred in 1921, the outstanding driest year of the series. On the other hand months with 25 days or more are fairly common, 28 being registered in March and December and 29 in October 1903.

No rain fell on the 27 days from May 30th to June 25th, 1925, or on the 26 days from September 2nd to 27th, 1912. On the four days following this last date, September 28th to October 1st, no less than 3·57 in. was recorded. In 1929 for the nine months January to September 10·02 in. was registered but the last three months of the year yielded 19·59 in., November and December totalling 15·74 in.

In the historic snowstorm of April 25th, 1908, which was particularly severe in the east Hampshire area,

Colonel Chrystie notes that drifts four feet deep were formed in the road near his home. There have been later snowstorms than April 25th, but surely none so severe as the blizzard on that date in 1908.

Colonel Chrystie died on June 14th, 1939, in his 98th year, while this note was being written, and it is to be hoped that arrangements can be made for the continuation of the record.

DR. EDWARD KIDSON

In the unexpected death of Dr. E. Kidson on 12th June, meteorology, especially meteorology in the southern hemisphere, has suffered a grevious loss. Dr. Kidson was not only a first rate scientist but he was an outstanding administrator with wide views embracing the whole world based on personal knowledge of America, Europe and Australasia.

Kidson was born at Bilston, Staffordshire on March 12th, 1882, of New Zealand parents. He was educated in New Zealand and graduated at the University of New Zealand with first class honours in Physics in 1904. He commenced his scientific career as an observer in terrestrial magnetism first at the Magnetic Observatory at Christchurch and then on the staff of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. During the war he served with distinction in the Meteorological Section of the Royal Engineers with the Salonika Force.

In 1921 Kidson joined the Australian Meteorological Service and for six years was the Assistant Director of the Melbourne Weather Bureau. In 1927 he was appointed Director of the New Zealand Meteorological Service.

Kidson from the first realised the coming development of aviation in Australasia and especially the important part which New Zealand, from its geographical position, would play in trans-Pacific aerial transport. He therefore looked ahead and laid plans for a meteorological

service in New Zealand capable of dealing with air lines between Australia and New Zealand across the Tasman Sea and between New Zealand and North America across the whole expanse of the Pacific Ocean.

When Kidson became Director of the Meteorological Office, Wellington, his staff consisted of four persons only, none of whom had had an adequate scientific training. It now consists of 45, several of whom are university trained men, and the latest methods of scientific meteorology are employed. Kidson himself twice visited Bergen to discuss with Dr. Bjerknes the application of his methods to southern hemisphere conditions.

Kidson attended the Conference of Empire Meteorologists in 1935 and then took part in the International Conference of Directors of Meteorological Services which met that year in Warsaw. Kidson was an excellent member of a Conference, very critical and always ready to stand up for his own views, but at the same time helpful with practical suggestions. He was a member of the International Meteorological Committee and took an active interest in all the doings of the International Meteorological Organization.

Kidson published many papers on meteorology and was an authority on Antarctic meteorology, having himself published a very complete discussion of the meteorological results of Shackleton's first Antarctic Expedition (1907–09). He was engaged on the results of Mawson's Antarctic Expeditions at the time of his death.

With the present rapid expansion of the Meteorological Services in Australia and New Zealand and the approaching retirement of Mr. Watt from the Directorship of the Melbourne Weather Bureau the advice and influence of such an experienced meteorologist as Dr. Kidson would have been invaluable to the local authorities. To lose such a councillor at this moment is a serious blow from which meteorology in Australasia will recover with difficulty.

G. C. S.

LETTERS TO THE EDITOR

Upward Discharge of Lightning from Cloud

In the interesting article on Atmospheric Electricity in the June number of the *Meteorological Magazine* mention is made of lightning discharges " between the cloud and the upper atmosphere " and Fig. 1 shows, diagrammatically, such a discharge going upwards to the ionosphere. But have any such discharges actually been observed? I have watched very many distant thunderstorms at night, and have sometimes seen what appeared to be flames going upwards for short distances above the thunder clouds, but these were very obviously streamers of cirriform cloud lit up by flashes inside the main cloud. I have never seen a flash of lightning going upwards from the top of a thunder cloud. C. J. P. CAVE.

Stoner Hill, Petersfield, Hants.
June 28th, 1939.

I am aware of no direct evidence for the occurrence of lightning discharges between a thundercloud and the upper atmosphere, but they are, I think, likely to occur on occasion. The pressure at great heights being low, the critical value of the field necessary to initiate a disruptive discharge is much lower in these regions than nearer the ground. If a thunder storm is large in vertical extent the critical field may, therefore, be reached above the cloud before it is reached within the cloud or between the cloud and the ground. Large dissipation of charge from the base of the cloud may have a similar effect. C. T. R. Wilson, in his article, " Atmospheric Electricity ", in the Dictionary of Applied Physics, Vol. III, suggests that some forms of " sheet lightning " may be due to disruptive discharges between a thundercloud and the upper atmosphere. P. A. SHEPPARD.

Imperial College of Science and Technology, S.W.7,
July 7th, 1939.

Terrestrial Radiation in May, 1939

The month of May, although not so cold as May 1938, has been marked by extreme terrestrial radiation. In this rather open position on the border of Hampshire at

the very moderate elevation of 370 ft., the mean grass minimum temperature was 9·2° F. below the mean of the screen minimum and on no fewer than 19 nights the difference between the two thermometers has equalled or exceeded 10° F. This is greater than in any month since January 1936 when the observations began, the next highest being 15 in April 1938 when the mean difference between the two thermometers was 9·1° F. On the 29th the difference was 17·3° F. the readings being, screen 43·1° F., grass 25·8° F. On the first of the month, on a dull rainy night, the difference was only 0·1° F. There were 13 nights with a grass minimum temperature of 30·4° or lower.

A. HAMPTON BROWN.

Badgecote, Boundstone, Farnham, Surrey,
May 31st, 1939.

[Mr. Hampton Brown states that since the above letter was written a difference of 19° F. between the screen and grass minimum has been recorded. This was on June 4th, the readings being, screen 46° F., grass 27° F.]

Range of Temperature in June, 1939

Attention may be called to the phenomenal range of temperature in northern England during the recent dry weather. At Houghall, in the Wear valley-bottom just outside Durham, four days in succession have given a range of over 40° F., breaking the previous records set up in 1929 and 1933. Screen temperatures were, June 3rd, max. 77° F., min. 30° F.; 4th, max. 84° F., min. 37° F.; 5th, max. 82° F., min. 40° F.; 6th, max. 87·4° F., min. 45° F. The maximum on the 6th was a record for this station. At Durham Observatory, the screen max. of 86·2° was the highest on record for June since at least 1881, and almost certainly, since 1850.

A maximum of 76° F. was recorded on Dun Fell (2,735 ft.) where, on the 12th, snow lay for several hours, with max. 41·5° F., min. 30° F.

GORDON MANLEY.

Wray Cottage, Long Garth, Durham.
June, 1939.

NOTES AND NEWS

Mr. J. S. Dines.

Mr. J. S. Dines retired from the Meteorological Office on June 30th, 1939, after a service of nearly 32 years. The younger son of the late Mr. W. H. Dines, F.R.S., he was educated at Emmanuel College, Cambridge, and obtained honours in the Mathematical Tripos, 1906. Dines and his elder brother have been connected with meteorology probably for a longer period than anyone now employed in the Meteorological Office. W. H. Dines was well known as one of the pioneers of upper-air meteorology in this country, and when quite a youth, Dines and his brother assisted their father in the work of flying kites carrying self-recording instruments from a steam-yacht at Crinan, in SW Scotland. This enterprise was supported by a Joint Committee of the British Association and the Royal Meteorological Society.

After leaving Cambridge, Dines spent a year assisting his father at their delightful home at Pyrton Hill near Watlington where kite flying for obtaining meteorological observations aloft was regularly carried out. This close association with his father, who was by profession an engineer, gave Dines the intimate knowledge and practice of engineering and instrument making which has been so great an asset to him in the position which he last held at the Meteorological Office, viz., Superintendent of Instruments and of Army Services.

Dines holds the distinction of being the first meteorologist in charge of an outstation (South Farnborough) where the meteorological work was specifically designed to assist aviation.

On the outbreak of the Great War he was transferred to London and took a prominent part in the work of the Forecast Division. In 1919 he became Superintendent of that Division.

He was author or joint-author of many papers, including several in the Reports of Wind Structure which were published before the War for the Advisory Committee for Aeronautics. A monograph on the wind

[*Facing page 180*

J. S. DINES, M.A.

at St. Helena and on the SE trade winds was his first work which he prepared when he entered the Meteorological Office in 1907. Dines was keenly interested, with Mr. C. J. P. Cave, in the rate of ascent of pilot balloons. After the disastrous flooding of the River Thames in London in 1928 he determined the meteorological factors which were favourable for a recurrence of the phenomenon.

Probably his best known work is the second and subsequent editions of " The Weather Map ", which describes in simple language the basic principles which are now used in the Meteorological Office for forecasting weather by means of synoptic charts.

His many friends both inside and outside the Office will join in wishing him every happiness in his retirement.

R.C.

The Dewpond " Myth ".

To the summer wanderer on the arid downs, the occasional isolated pond may well be amazing and mysterious. Its shelving banks merge so gradually into the surrounding levels that it appears at first glance to be filled to the brim, and one naturally wonders how it can be maintained. Thus, when the term " dewpond " was given wide currency by the Hubbards' fascinating book, it speedily became popular, for to some minds, labelling a thing is as good as explaining it. The facile explanation was not wanting however; dewponds are " insulated " by a layer of non-conducting straw, they grow cold by radiation at night, and dew forms on them.

Mr. E. A. Martin tried to dispose of this idea by observing the temperature of the water surface of a dewpond at night; he found, as was to be expected, that it very rarely falls to the dew point. This should have killed the dewpond myth, but " the body won't lie down". That is the excuse for this agreeable little book.* As the source of supply, the author pours scorn on dew and has little more respect for Martin's idea of hill fogs.

* *Dewponds in Fable and Fact*. By Alfred J. Pugsley. Pp. X + 62, illus. London, Country Life Ltd., 3/6.

He adopts instead, the idea favoured by most meteorologists that these ponds are simply open-air reservoirs for the rain which runs down their wide, sloping margins, often as much as twice the area of the pond itself. With the main points of his argument there is already general agreement, but the details are open to criticism. He quotes figures to show that in a normal year rainfall exceeds evaporation by a considerable figure, but he does not discuss how far this is true in a dry summer. That the point is important the following figures will show: at Camden Square in 1921 the evaporation exceeded the rainfall for the year as a whole and in each month from April to August inclusive, while for May to July the evaporation was 10·9 inches compared with a rainfall of only 1·5 inches. It is true that on the hill tops the rainfall is greater than at Camden Square, but in view of the much stronger winds it is doubtful if the evaporation is less.

The arguments about temperature of the water surface are sound enough, but no one seems to have discussed the possibility that dew may form on the surround and trickle down into the pond. The conductivity of earth or cement is so low that an insulating layer of straw would be an unnecessary refinement; in any case the underlying dry chalk with abundant air spaces would serve the same purpose. All that is required is a smooth, impervious slope; under suitable conditions some access of water in this way seems certain.

It is quite possible therefore for the " body " to sit up and argue that it is not really so dead as all that! In normal times rainfall is ample to maintain a pond, but in a dry summer the balance tips heavily the other way, and even a few gallons of water delivered by trickles of dew, by sea fogs and in other " occult " ways may just possibly make the difference between a pond drying up and maintaining a precarious existence. None the less, the exponents of the " pure rainfall " theory have a very strong case, and it is good that it should be presented again.

C. E. P. B.

Royal Meteorological Society.

A meeting of the Society was held on Wednesday, the 21st instant, in the Society's rooms at 49, Cromwell Road, South Kensington; Dr. B. A. Keen, F.R.S., President, was in the Chair.

The following papers were read and discussed:—

The nature of atmospheric opacity: a study of visibility observations in the British Isles.—By H. L. Wright, M.A.

A station may be classified, as to visibility, by using visibility frequencies to evaluate the atmospheric opacity, which is directly proportional to the extinction coefficient. Mean values of the atmospheric opacity on clear and foggy days at various stations in the British Isles are used to infer the contribution of various types of nuclei and particles to the opacity and to the production of fog. It is concluded that sea-salt nuclei and smoke particles play a leading part in the determination of visibility but that the effect of combustion nuclei, unless they are extremely numerous, is negligible. Water fogs are due to sea-salt nuclei and if supersaturation is attained they may thicken considerably owing to condensation of water on the nuclei. Such condensation does not occur on combustion nuclei if sea-salt nuclei are present.

The variation in opacity with relative humidity is calculated theoretically and the calculations are applied to observations of nuclei, particles, and relative humidity at Kew Observatory in the afternoon. Fair agreement is found between the calculated values of opacity and those which correspond to the visibility as observed.

One appendix gives factors for comparing the visibility of reflecting objects with the visibility of a black object silhouetted against the sky. In a second appendix the increase in opacity during precipitation is calculated.

A new theodolite for following fast-moving objects, especially for making pilot balloon observations of greater accuracy.—By Prof. L. W. Pollak, Ph.D.

A new pilot balloon theodolite is described, the essential feature of which is that the reading arrangements (verniers) remain stationary relatively to the vertical and horizontal scales from one reading until the next, so that the observer is able to follow the balloon continuously.

Correlations between monthly rainfall at eleven stations in the British Isles.—By D. A. Boyd, B.A.

The paper is based upon rainfall records for the months of January, April, July and October at eleven stations in the British Isles over a period 1870–1929. The means, variances and covariances were computed. Percentage standard errors were obtained and mapped, the general distribution proving fairly similar in all months.

A correlation coefficient for each pair of stations in each of the chosen months was evaluated and transformed to z. The value of z was dependent to a considerable extent on the inter-station distance and bearing. The linear regression of z on distance between stations was significant in each month, but the quadratic term was small and non-significant. The remaining two terms of the regression, associated with the bearing between pairs of stations, reached significance on only two occasions out of the possible eight; but as a whole, they gave a reasonably coherent picture of monthly changes in the inter-station bearing at which correlation reached a maximum.

To account for such changes, and for changes in z, data given by other workers were examined. The variations appeared to be closely associated with the persistence of a pressure gradient for winds from the south-westerly quadrant.

A large part of the residual variance is shown to be due to a marked regional variation, the association between monthly rainfalls being greatest in the south and least in the north. Maps of the residual z's show that the association within groups of stations on the west coast or on the east coast was greater than that between the west and east coast groups.

The Howard Prize, 1939.

The Council of the Royal Meteorological Society has awarded the Howard Prize (an aneroid barometer, given annually for the best essay on a selected meteorological subject) to Cadet V. A. McMillan, of H.M.S. *Conway* School Ship. Cadet C. D. Thorpe, also of H.M.S. *Conway*, was placed second in the competition. The subject of the essays was " The barometer and its use in meteorology ".

A Shower of Frogs.

An account of a shower of frogs at Trowbridge, Wilts in the afternoon of June 16th appeared in *The Times* of the 17th. Mr. E. Ettles, superintendent of the municipal swimming pool stated that about 4.30 p.m. he was caught in a heavy shower of rain and, while hurrying to shelter, heard behind him a sound as of the falling of lumps of mud. Turning, he was amazed to see hundreds of tiny frogs falling on the concrete path around the bath. Later, many more were found to have fallen on the grass nearby.

A trough of low pressure was moving eastwards on that day, rain was reported from many places in the area and Torquay reported a line-squall in the afternoon. It is possible that the squall occurred also at Trowbridge,

and that this was strong enough to have forced the frogs from the water, although Mr. Norman's theory given below may be the more probable explanation.

Showers of frogs are not uncommon and have been reported from time to time. Several subsequent letters have appeared in *The Times* citing instances at home and abroad.

Showers of fish have been reported from very early days, notably in India during stormy weather. Accounts and suggested explanations are given by Dr. S. L. Hora in the *Journal of the Asiatic Society of Bengal* 1933 and by J. R. Norman in the *Natural History Magazine* 1928. Mr. Norman suggests that in the case of frogs it is possible that numbers of tadpoles may undergo metamorphosis simultaneously, hide if the weather is at all dry and come out into the open with the first rain so suddenly that they appear to have fallen from the sky.

A letter to *The Times* of June 29th reports rains of fishes from Bourke, N.S.W. with the engaging theory that the spawn is drawn up from lakes and rivers in waterspouts, that it germinates in the clouds and that when full grown the fish fall to the ground.

Other extraordinary " showers " are on record, birds, larvæ, worms, oranges, pebbles, and so on; an amusing account " Showers of What Not " is given by Ivan E. Houk in *Tycos Rochester* April 1930. Perhaps the most remarkable was a shower of fossils (partly fossilised hazel nuts) at Dublin in 1867.

Coloured rains and snows of various hues are also on record, notably "showers of blood" in desert areas. The theory of the formation of coloured rain is discussed by C. J. Boyden in the *Quarterly Journal of the Royal Meteorological Society* 1937.

An Unusual Electrical Discharge at Wellington.

At 23h. 25m. New Zealand Standard Time, on April 12th, 1939, the writer and two friends came out of a house on Kelburn Parade, Wellington, New Zealand, altitude about 130 metres, and were immediately arrested by what appeared to be a searchlight playing on the under surface of broken clouds lying over the Wellington

Harbour. The clouds were very low fracto-cumulus, at about 200 metres, as judged by their level on the hills. As no searchlight beam was visible, one observer said that he thought that the phenomenon was due to " lightning ".

The writer then descended Mount Street, where he had a much better view. It was seen that the clouds were moving very slowly from the south, were about six-tenths in amount (mostly overhead and towards the east) and were illuminated almost continuously by silent discharges which passed comparatively slowly, like " blushes " (though the light was whitish) over their surfaces. The slower discharges were estimated to take as long as half a second to pass over the surface of a cloud. Others were much quicker and seemed to be brighter. Occasionally a bright but silent flash passed very rapidly from one cloud to the next. Although now and then several clouds discharged simultaneously, for the most part the " blushes " affected first one cloud and then another.

The clouds were kept under observation until 23h. 40m. Standard Time, when the writer went indoors. During the whole of this period there was no cessation of the discharges.

At 22h. 30m. Standard Time, on the same night, Mr. Thompson, of the store in Kelburn Park, saw on the southern horizon a bright light which he took to be the aurora australis. This is confirmed by reports of the aurora in the South Island received by Mr. Geddes of the Carter Observatory, Wellington.

C. E. PALMER.

In forwarding this note Dr. E. Kidson remarked, " On the date in question, New Zealand was covered by a rather intense anticyclone and Wellington was not far from the centre, which was to the southwest. The sky was clear above the low inversion in which the cloud mentioned by Mr. Palmer occurred, and the atmosphere must have been very stable. Dry weather had been experienced for a long time throughout most of the country. The phenomenon could not have been due to any such effect as reflection of auroral lights."

Sunshine, June 1939

The distribution of bright sunshine for the month was as follows:—

	Total hrs.	Diff. from average hrs.		Total hrs.	Diff. from average hrs.
Stornoway ..	163	– 4	Chester ..	234	+39
Aberdeen ..	209	+28	Ross-on-Wye	217	+10
Dublin ..	205	+23	Falmouth ..	261	+34
Birr Castle ..	209	+49	Gorleston ..	237	+26
Valentia ..	249	+76	Kew.. ..	220	+17

Kew temperature, mean, 59·5° F.: diff. from average, –0·4° F.

OBITUARY

SIR FRANCIS DYKE ACLAND. We regret to announce the death on June 8th, 1939, of the Rt. Hon. Sir Francis Dyke Acland, Bart., P.C., of Killerton, Devon. A climatological station has been maintained by Sir Francis and other members of his family since 1900 and the records have been published regularly since 1907, in the *Meteorological Record* of the Royal Meteorological Society till 1911 and from 1912 in the *Monthly Weather Report.*

DR. A. E. KENNELLY. We regret to announce the death on June 18th, 1939, of Dr. A. E. Kennelly, co-discoverer with Oliver Heaviside of the ionized layer surrounding the earth.

COLONEL GEORGE CHRYSTIE. We regret to announce the death on June 14th, 1939, of Colonel Chrystie who for 40 years maintained a rainfall record at Short Heath Lodge, Farnham. An account of this record is given on page 173.

Erratum

With reference to the note on page 25 of the February issue of the Magazine we now learn that Lieutenant-Commander F. W. Reichelderfer was commissioned Commander in the U.S. Navy on June 23rd, 1938.

Rainfall : June 1939 : England and Wales

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Lond'n	Camden Square......	1·20	59	*Warw*	Birminghm, Edgbaston	1·61	69
Surrey	Reigate, Wray Pk. Rd.	1·36	65	*Leics* .	Thornton Reservoir...	1·48	69
Kent .	Tenterden, Ashenden.	1·70	89	,, .	Belvoir Castle........	2·81	147
,, .	Folkestone, I. Hospital	1·75	..	*Rutl'd*	Ridlington	2·27	118
,, .	Margate, Cliftonville..	1·32	75	*Lincs*.	Boston, Skirbeck.....	1·87	103
,, .	Edenb'dg.,Falconhurst	·84	38	,, .	Cranwell Aerodrome..	1·88	112
Sussex	Compton, Compton Ho	2·12	85	,, .	Skegness, Marine Gdns	2·08	116
,, .	Patching Farm........	1·08	53	,, .	Louth, Westgate.....	3·25	150
,, .	Eastbourne, Wil. Sq..	1·44	78	,, .	Brigg, Wrawby St....	2·40	..
Hants.	Ventnor, Roy.Nat.Hos.	1·78	97	*Notts* .	Mansfield, Carr Bank..	2·14	95
,, .	Southampton, East Pk	1·92	96	*Derby*.	Derby, The Arboretum	·82	35
,, .	Ovington Rectory....	2·47	106	,, .	Buxton, Terrace Slopes	2·83	88
,, .	Sherborne St. John...	1·45	68	*Ches* .	Bidston Obsy........	2·54	115
Herts .	Royston, Therfield Rec	2·31	103	*Lancs*.	Manchester, Whit. Pk.	2·58	98
Bucks.	Slough, Upton.......	1·26	61	,, .	Stonyhurst College...	4·58	149
Oxford	Oxford, Radcliffe.....	1·97	88	,, .	Southport, Bedford Pk	3·12	144
N'hant	Wellingboro,Swanspool	1·78	85	,, .	Ulverston, Poaka Beck	3·18	98
,, .	Oundle	1·62	..	,, .	Lancaster, Greg Obsy.	3·69	144
Beds .	Woburn, Exptl. Farm.	2·92	149	,, .	Blackpool	3·01	138
Cambs	Cambridge, Bot. Gdns.	1·96	93	*Yorks*.	Wath-upon-Dearne ...	1·82	82
,, .	March	2·02	103	,, .	Wakefield,Clarence Pk.	1·48	69
Essex.	Chelmsford,CountyGns	1·38	73	,, .	Oughtershaw Hall....	4·52	..
,, .	Lexden Hill House....	1·45	..	,, .	Wetherby, Ribston H.	..	..
Suff .	Haughley House.....	1·64	..	,, .	Hull, Pearson Park...	3·19	155
,, .	Rendlesham Hall.....	..	..	,, .	Holme-on-Spalding...	2·31	105
,, .	Lowestoft Sec. School.	1·25	69	,, .	Felixkirk, Mt. St. John	2·46	112
,, .	Bury St. Ed.,WestleyH	2·02	96	,, .	York, Museum	1·67	81
Norf..	Wells, Holkham Hall.	2·57	131	,, .	Pickering, Houndgate.	1·97	93
Wilts .	Porton, W.D. Exp'lStn	1·73	90	,, .	Scarborough.........	3·21	174
,, .	Bishops Cannings	2·59	107	,, .	Middlesbrough.......	2·08	110
Dorset	Weymouth, Westham.	2·19	123	,, .	Baldersdale, Hury Res.	2·43	103
,, .	Beaminster, East St ..	3·38	150	*Durhm*	Ushaw College.......	2·61	121
,, .	Shaftesbury	2·97	..	*Norl'd*	Newcastle, Leazes Pk.	2·07	98
Devon.	Plymouth, The Hoe...	3·61	167	,, .	Bellingham, Highgreen	2·36	103
,, .	Holne, Church Pk.Cott	5·07	177	,, .	Lilburn Tower Gdns..	1·89	91
,, .	Teignmouth, Den Gdns	2·55	133	*Cumb*.	Carlisle, Scaleby Hall.	3·09	123
,, .	Cullompton	3·17	150	,, .	Borrowdale,Seathwaite	12·00	197
,, .	Sidmouth, U.D.C.....	2·82	..	,, .	Thirlmere,DaleHeadH.	6·20	146
,, .	Barnstaple,N. Dev.Ath	1·07	48	,, .	Keswick, High Hill...	4·68	161
,, .	Dartm'r,Cranmere P'l	4·90	..	,, .	Ravenglass, The Grove	3·78	145
,, .	Okehampton, Uplands.	3·54	128	*West* .	Appleby, Castle Bank.	2·80	122
Cornw	Redruth, Trewirgie...	3·00	120	*Mon* .	Abergavenny, Larchf'd	2·28	93
,, .	Penzance, MorrabGdns	2·36	106	*Glam* .	Ystalyfera, Wern Ho..	5·46	145
,, .	St. Austell, Trevarna..	3·02	116	,, .	Treherbert, Tynywaun	6·36	..
Soms .	Chewton Mendip.....	3·76	127	,, .	Cardiff, Penylan......	1·85	74
,, .	Long Ashton	2·11	83	*Carm* .	Carmarthen,M.&P.Sc.	3·83	130
,, .	Street, Millfield	3·52	170	*Card* .	Aberystwyth	2·31	..
Glostr.	Blockley	2·45	..	*Radn'r*	Bir. W. W. Tyrmynydd	3·28	100
,, .	Cirencester, Gwynfa ..	2·25	94	*Mont* .	Lake Vyrnwy........	3·69	117
Here .	Ross-on-Wye	1·61	74	*Flint* .	Sealand Aerodrome...	2·00	98
,, .	Kington, Lynhales....	1·88	80	*Mer* .	Blaenau Festiniog....	7·06	118
Salop .	Church Stretton......	1·45	..	,, .	Dolgelley, Bontddu...	3·82	110
,, .	Shifnal, Hatton Grange	1·69	76	*Carn* .	Llandudno	1·74	92
,, .	Cheswardine Hall	2·22	91	,, .	Snowdon, L. Llydaw 9	12·45	..
Worc .	Malvern, Free Library.	2·00	86	*Angl* .	Holyhead, Salt Island.	1·62	75
,, .	Ombersley, Holt Lock.	1·81	80	,, .	Lligwy.............	1·92	..
Warw	Alcester, Ragley Hall.	2·16	95	*I.Man*	Douglas, Boro' Cem...	1·97	81

Erratum : Aberystwyth, May *for* 1·78 *read* 1·06.

Rainfall : June 1939 : Scotland and Ireland

Co.	Station.	In.	Per cent of Av.	Co.	Station.	In.	Per cent of Av.
Guern .	St.PeterP't.GrangeRd.	2·18	118	*R&C* .	Stornoway, C.G.Stn...	1·30	59
Wig .	Pt. William, Monreith.	1·71	73	*Suth* .	Lairg	1·47	70
,, .	New Luce School.....	2·58	89	,, .	Skerray Borgie.......	2·11	..
Kirk .	Dalry, Glendarroch...	3·37	121	,, .	Melvich	1·82	94
Dumf.	Eskdalemuir Obs.....	4·23	134	,, .	Loch More, Achfary..	3·51	95
Roxb .	Hawick, Wolfelee	2·83	121	*Caith* .	Wick	1·23	68
,, .	Kelso, Broomlands....	1·63	77	*Orkney*	Deerness	1·20	65
Peebs .	Stobo Castle.........	1·55	66	*Shet* .	Lerwick Observatory.	1·62	91
Berw .	Marchmont House....	1·80	78	*Cork* .	Cork, University Coll.	1·78	70
E.Lot.	North Berwick Res...	1·55	93	,, .	Roches Point, C.G.Stn.	1·50	56
Midl .	Edinburgh, Blackfd. H	1·31	65	,, .	Mallow, Waterloo	1·88	85
Lanark	Auchtyfardle	1·76	..	*Kerry*.	Valentia Observatory.	3·13	98
Ayr .	Kilmarnock, Kay Park	2·08	..	,, .	Gearhameen	4·80	96
,, .	Girvan, Pinmore	2·28	79	,, .	Bally McElligott Rec.	2·48	..
,, .	Glen Afton, Ayr San..	2·82	94	,, .	Darrynane Abbey....	2·01	64
Renf .	Glasgow, Queen's Park	1·80	78	*Wat* .	Waterford, Gortmore.	2·44	93
,, .	Greenock, Prospect H.	1·72	55	*Tip* .	Nenagh, Castle Lough.	2·14	87
Bute .	Rothesay, Ardencraig.	2·88	94	,, .	Cashel, Ballinamona..	2·73	120
,,	Dougarie Lodge......	2·66	98	*Lim* .	Foynes, Coolnanes....	2·28	88
Argyll	Loch Sunart, G'dale..	3·40	106	,, .	Limerick, Mulgrave St.	1·85	77
,,	Ardgour House	5·92	..	*Clare* .	Inagh, Mount Callan..	3·28	..
,,	Glen Etive	3·97	84	*Wexf* .	Gorey, Courtown Ho..	2·02	83
,,	Oban	2·66	..	*Wick* .	Rathnew, Clonmannon	2·03	..
,,	Poltalloch	..	..	*Carlow*	Bagnalstown FenaghH	2·11	85
,,	Inveraray Castle	4·22	107	,, .	Hacketstown Rectory.	2·04	73
,,	Islay, Eallabus	1·97	75	*Leix* .	Blandsfort House	2·45	95
,, .	Mull, Benmore.......	6·70	85	*Offaly*.	Birr Castle	2·28	99
,,	Tiree	2·01	79	*Kild* .	Straffan House.......	..	..
Kinr .	Loch Leven Sluice....	1·77	81	*Dublin*	Dublin, Phoenix Park.	2·12	107
Fife .	Leuchars Aerodrome..	1·41	84	*Meath*.	Kells, Headfort......	2·10	79
Perth .	Loch Dhu	4·20	101	*W.M* .	Moate, Coolatore.....	2·02	..
,, .	Crieff, Strathearn Hyd.	1·94	73	,, .	Mullingar, Belvedere..	2·09	80
,, .	Blair Castle Gardens..	1·38	70	*Long* .	Castle Forbes Gdns ..	3·86	148
Angus.	Kettins School.......	1·62	78	*Galway*	Galway, Grammar Sch.	1·42	55
,, .	Pearsie House	1·43	..	,, .	Ballynahinch Castle ..	2·10	59
,, .	Montrose, Sunnyside..	1·33	80	,, .	Ahascragh, Clonbrock.	2·95	105
Aberd.	Balmoral Castle Gdns.	1·80	106	*Rosc* .	Strokestown, C'node..	2·40	102
,, .	Logie Coldstone Sch ..	..	..	*Mayo*.	Blacksod Point	2·24	80
,, .	Aberdeen Observatory.	1·29	75	,, .	Mallaranny..........	2·94	..
,, .	New Deer SchoolHouse	1·50	75	,, .	Westport House......	2·52	93
Moray	Gordon Castle	1·48	73	,, .	Delphi Lodge........	6·63	115
,, .	Grantown-on-Spey ...	2·54	113	*Sligo* .	Markree Castle.......	1·98	66
Nairn.	Nairn..............	1·62	92	*Cavan*.	Crossdoney, Kevit Cas.	2·77	..
Inv's .	Ben Alder Lodge.....	2·11	..	*Ferm* .	Crom Castle	4·63	171
,, .	Kingussie, The Birches	1·27	..	*Arm'h*	Armagh Obsy........	1·94	77
,, .	Loch Ness, Foyers....	1·42	64	*Down*.	Fofanny Reservoir ...	4·65	..
,, .	Inverness, Culduthel R	1·08	57	,, .	Seaforde	1·63	59
,, .	Loch Quoich, Loan...	4·14	..	,, .	Donaghadee, C. G. Stn.	1·80	77
,, .	Glenquoich..........	4·25	87	*Antrim*	Belfast,Queen's Univ .	1·86	75
,, .	Arisaig House	2·33	71	,, .	Aldergrove Aerodrome	1·87	78
,, .	Glenleven, Corrour ...	3·27	97	,, .	Ballymena, Harryville.	2·29	79
,, .	Ft. William, Glasdrum	3·51	..	*Lon* .	Garvagh, Moneydig...	4·21	..
,, .	Skye, Dunvegan	2·19	..	,, .	Londonderry, Creggan.	2·50	89
,, .	Barra, Skallary	1·69	..	*Tyrone*	Omagh, Edenfel......	2·41	85
R&C .	Tain, Ardlarach......	1·27	62	*Don* .	Malin Head.........	2·03	77
,, .	Ullapool	1·15	49	,, .	Dunfanaghy	1·80	75
,, .	Achnashellach	2·53	64	,, .	Dunkineely..........	1·71	..

Reference Table: Climatological Table of the British Empire.

Stations.	Lat.	Long.	Height above M.S.L.	*Hour of Observation	Authority.	Period of Normals. Pressure.	Temperature.	Rainfall.
			Ft.					
London, Kew Obsy. . .	51°28′N.	0°19′W.	34	7	Meteorological Office, Air Ministry, London.	'81–'15	'01–'30	'81–'15
Gibraltar	36° 6′N.	5°21′W.	400	7	Do. do.	'52–'30	'52–'32	—
Malta.	35°54′N.	14°31′E.	233	7	Do. do.	'52–'23	'53–'23	'53–'23
St. Helena	15°57′S.	5°40′W.	2,000	6½	W. E. Jackson, Esq., Longwood Villa	'25–'35	'25–'36	'25–'35
Sierra Leone . .	8°29′N.	13°14′W.	181	7	British West African Meteorological Service.	'77–'20	—	'74–'20
Lagos, Nigeria . .	6°27′N.	3°24′E.	10	7	Do. do.	'91–'26	'91–'27	'91–'26
Kaduna, Nigeria . .	10°32′N.	7°25′E.	1,915	7	Do. do.	—	'17–'31	'16–'31
Zomba, Nyasaland . .	15°23′S.	35°18′E.	3,020	9	Director of Agriculture	'08–'32	'92–'26	'92–'26
Salisbury, Rhodesia. .	17°48′S.	31° 5′E.	4,831	9	Department of Agriculture	'21–'36	'97–'23	—
Cape Town	33°56′S.	18°29′E.	40	8½	H.M. Astronomer	'41–'28	'57–'24	'41–'28
Johannesburg . .	26°11′S.	28° 4′E.	5,925	8½	The Union Astronomer, Johannesb'g	'04–'28	'04–'28	'88–'24
Mauritius	20° 6′S.	57°33′E.	181	9	Royal Alfred Observatory	'75–'30	'61–'19	'71–'30
Calcutta, Alipore Obsy.	22°32′N.	88°20′E.	22	8	Director General of Observatories, Poona.	'89–'10	'77–'20	'29–'20
Bombay	18°54′N.	72°49′E.	37	8	Do. do.	'47–'16	'78–'20	'47–'16
Madras	13° 4′N.	80°15′E.	22	8	Do. do.	'89–'20	'75–'20	1813–1920
Colombo, Ceylon . .	6°54′N.	79°52′E.	24	9½	Surveyor-General, Colombo . .	'69–'20	'69–'20	'69–'20
Singapore	1°18′N.	103°53′E.	9	10	Malaya Meteorological Service, Singapore.	'98–'22	'98–'22	'69–'20
Hongkong	22°18′N.	114°10′E.	109	9	Director, Royal Observatory . .	'84–'28	'84–'18	'84–'28
Sandakan	5°50′N.	118° 7′E.	182	9	Principal Medical Officer, N. Borneo	—	'79–'95 ; '04–'29	'79–'95 ; '04–'29
Sydney	35°51′S.	151°13′E.	138	9	Commonwealth Meteorologist, Melbourne.	69 years	69 years	69 years
Melbourne	37°49′S.	144°58′E.	115	9	Do. do.	70 years	72 years	72 years
Adelaide	34°56′S.	138°35′E.	140	9	Do. do.	80 years	80 years	98 years
Perth, W. Australia. .	31°57′S.	115°51′E.	197	9	Do. do.	43 years	31 years	52 years
Coolgardie	30°57′S.	121°10′E.	1,389	9	Do. do.	'97–'31	'97–'21	'93–'27
Brisbane	27°28′S.	153° 2′E.	125	9	Do. do.	41 years	41 years	'41–'50 ; '59–'32
Hobart, Tasmania . .	42°53′S.	147°20′E.	177	9	Do. do.	43 years	57 years	85 years
Wellington, N.Z. . .	41°16′S.	174°46′E.	394	9	Meteorological Office, Wellington . .	'64–'23	66 years	'62–'23
Suva, Fiji	18° 8′S.	178°26′E.	12	8	The Harbour Master, Suva . .	'86–'28	'86–'28	'86–'28
Apia, Samoa . .	13°48′S.	171°46′W.	6½	9	The Director, Apia Observatory . .	'90–'24	'90–'23	'90–'24
Kingston, Jamaica . .	17°55′N.	76°12′W.	111	7	Government Meteorologist . .	'81–'98 ; '08–'22	'80–'99 ; '07–'18	'70–'19
Grenada, W.I. . .	12° 5′N.	61°46′W.	617	9	Supt. of Prisons, Richmond Hill . .	'91–'25	'87 ; '91–'29	'91–'29
Toronto	43°40′N.	79°24′W.	379	8	Director, Meteorological Service of Canada.	'86–'21	'73–'20	'74–'20
Winnipeg	49°53′N.	97° 7′W.	760	7	Do. do.	'86–'20	'73–'20	'86–'20
St. John, N.B. . .	45°17′N.	66° 4′W.	119	9	Do. do.	'02–'26	45 years	'61–'10
Victoria, B.C. . .	48°24′N.	123°19′W.	230	9	Do. do.	'00–'24	'91–'25	'91–'25

* Local or zone time.

Notes:—The mean wet bulb, relative humidity and mean cloud amount refer to the morning hour of observation only. The pressure is reduced to mean of day.

Climatological Table for the British Empire, January, 1939

STATIONS.	Pressure: Mean of Day M.S.L. (mb.)	Pressure: Diff. from Normal. (mb.)	Temperature: Absolute Max. (°F.)	Temperature: Absolute Min. (°F.)	Temperature: Mean Values Max. (°F.)	Temperature: Mean Values Min. (°F.)	Temperature: Mean Values ½ Max. and Min. (°F.)	Temperature: Mean Values Diff. from Normal. (°F.)	Temperature: Mean Wet Bulb. (°F.)	Relative Humidity. (%)	Mean Cloud Am'nt (0–10)	Precipitation: Am'nt. (in.)	Precipitation: Diff. from Normal. (in.)	Precipitation: Days.	Bright Sunshine: Hours per day.	Bright Sunshine: Percentage of possible.
London, Kew Obsy	1003·4	−14·2	54	26	45·5	38·3	41·9	+ 1·5	39·9	88	8·7	4·32	+ 2·56	20	1·5	18
Gibraltar	1020·0	− 1·5	68	43	59·8	50·3	55·1	+ 0·2	50·2	81	4·7	2·50	—	11	5·9	59
Malta	1015·7	− 1·3	73	46	59·8	50·6	55·2	− 0·1	49·9	78	5·5	1·26	− 1·95	10	6·5	65
St. Helena	1015·4	− 0·6	70	57	66·6	59·6	63·1	− 0·3	60·5	95	9·7	2·19	+ 0·15	18	—	—
Freetown, Sierra Leone	1011·3	+ 2·2	89	71	86·7	74·6	80·7	—	72·9	87	6·2	1·22	+ 0·81	4	—	—
Lagos, Nigeria	1010·0	+ 0·4	89	66	87·3	71·9	79·6	− 1·3	72·9	96	4·1	0·34	− 0·70	3	6·7	57
Kaduna, Nigeria	1011·2	—	97	53	87·8	58·8	73·3	− 0·3	51·8	40	2·5	0·00	0·00	0	9·2	80
Zomba, Nyasaland	1006·8	− 0·8	85	62	79·0	65·4	72·2	− 0·6	68·7	84	7·6	19·33	+ 8·23	21	—	—
Salisbury, Rhodesia	1010·7	+ 0·3	83	56	76·2	59·6	67·9	− 1·8	62·4	78	8·2	9·47	—	21	5·6	43
Cape Town	1014·0	+ 0·6	93	56	80·8	61·7	71·3	+ 1·4	62·5	67	3·4	0·00	− 0·68	0	—	—
Johannesburg	1010·4	+ 0·4	87	49	76·4	55·0	65·7	− 1·0	57·6	73	6·0	3·74	− 2·43	15	7·3	54
Mauritius	1012·3	+ 0·6	91	66	88·0	71·4	79·7	+ 0·4	73·4	65	5·0	1·56	− 6·60	16	9·5	72
Calcutta, Alipore Obsy.	1015·6	+ 0·4	89	51	82·5	56·3	69·4	+ 2·8	57·6	90	1·6	0·06	− 0·36	0*	—	—
Bombay	1013·0	− 0·6	92	64	84·8	68·4	76·6	+ 1·1	66·6	72	1·5	0·00	− 0·10	0*	—	—
Madras	1013·8	− 0·3	86	63	83·8	68·0	75·9	− 0·3	69·2	78	5·0	0·65	− 0·49	1*	—	—
Colombo, Ceylon	1011·2	+ 0·4	88	67	84·9	71·1	78·0	− 1·5	72·4	74	5·0	6·61	+ 3·36	12	7·8	66
Singapore	1009·6	− 0·8	89	72	85·3	73·9	79·6	− 0·1	76·2	76	7·7	10·69	+ 0·80	19	5·5	46
Hongkong	1020·2	+ 0·5	74	50	65·5	56·8	61·1	+ 0·9	57·1	80	7·6	1·10	− 0·22	7	4·2	39
Sandakan	1009·4	—	86	72	84·1	75·0	79·5	− 0·3	76·2	88	9·1	23·35	+ 3·95	25	—	—
Sydney, N.S.W.	1011·2	− 1·2	114	60	78·6	65·9	72·3	+ 0·7	66·9	67	6·2	3·23	− 0·44	13	6·3	45
Melbourne	1011·0	− 1·9	114	49	81·7	58·3	70·0	+ 2·6	60·1	52	5·5	0·31	− 1·58	5	8·6	60
Adelaide	1009·5	− 3·5	118	55	95·1	65·0	80·1	+ 6·4	64·6	32	3·6	1·30	+ 0·58	4	10·6	75
Perth, W. Australia	1009·7	− 2·8	98	51	79·4	60·1	69·7	− 4·1	62·5	57	5·7	0·68	+ 0·34	5	10·3	85
Coolgardie	1007·6	− 3·8	110	55	88·1	64·9	76·5	− 0·9	64·8	63	5·2	6·43	+ 5·97	6	—	—
Brisbane	1010·6	− 0·7	100	65	85·6	70·6	78·1	+ 1·6	71·9	73	7·4	1·93	− 4·52	10	6·9	50
Hobart, Tasmania	1011·2	− 0·9	93	43	70·7	50·9	60·8	− 1·2	52·1	49	5·9	0·65	− 1·18	8	8·7	58
Wellington, N.Z.	1006·8	− 6·5	74	42	66·0	51·8	58·9	− 3·6	54·8	68	6·3	0·89	− 2·44	7	8·6	58
Suva, Fiji	1005·9	− 1·6	91	70	65·6	74·3	79·9	0·0	75·7	87	8·1	30·71	+19·28	27	4·6	35
Apia, Samoa	1008·7	+ 0·8	87	72	83·6	74·2	78·9	− 0·1	75·7	83	7·8	59·57	+42·52	28	5·7	45
Kingston, Jamaica	1015·2	+ 0·1	89	64	86·2	68·2	77·2	+ 0·4	65·5	82	4·3	0·59	− 0·37	6	6·7	60
Grenada, W.I.																
Toronto	1016·5	− 1·4	52	−9	30·4	17·0	23·7	+ 1·5	—	—	8·5	2·25	− 0·54	21	1·8	19
Winnipeg	1015·9	− 5·0	27	−32	13·6	−4·7	4·5	+ 8·4	—	—	7·4	0·79	− 0·12	12	2·1	21
St. John, N.B.	1012·0	− 3·5	44	−8	26·5	10·9	18·7	− 0·5	14·2	70	5·9	3·36	− 1·44	13	4·0	43
Victoria, B.C.	1015·7	− 0·3	51	33	46·0	39·8	42·9	+ 3·9	41·3	92	8·9	4·65	+ 0·11	23	1·6	18

* For Indian stations a rain day is a day on which 0·1 in. or more rain has fallen.

Daily Readings at Kew Observatory, June 1939

Date.	Pressure, M.S.L. 13h.	Wind, Dir. 13h.	Wind, Force 13h.	Temp. Min.	Temp. Max.	Rel. Hum. 13h.	Rain.	Sun.	Remarks.
	mb.			°F.	°F.	%	in.	hrs.	
1	1026·0	NE	4	48	64	62	—	8·1	
2	1024·5	ENE	5	50	74	45	—	12·3	
3	1025·3	NE	5	49	72	31	—	14·7	
4	1024·4	E	5	51	74	31	—	15·3	
5	1024·5	E	5	54	76	27	—	15·2	
6	1020·8	ENE	3	59	84	45	—	13·5	
7	1021·1	NNE	2	59	85	39	—	13·0	
8	1023·3	NE	3	57	72	52	—	11·1	
9	1026·7	ESE	3	49	67	45	—	13·7	
10	1015·1	SW	3	47	76	48	—	14·3	
11	1006·9	NNW	3	53	64	76	0·26	4·5	r–r_0 0h–7h, tlr 24h.
12	1011·8	W	3	47	60	40	trace	8·9	qpr_0 14h, pr_0 17h.
13	1016·3	NW	3	43	57	45	trace	6·6	pr_0 14h, 15h & 16h.
14	1013·1	SSW	4	52	64	60	trace	2·2	pr_0 15h & 16h.
15	1010·3	SSW	4	56	61	73	0·01	0·3	d_0 8h–9h, r_0 24h.
16	1007·9	S	3	57	63	91	0·22	1·4	r_0–r 0h–6h & 9h–12h.
17	1016·3	SW	3	49	63	64	—	7·6	
18	1013·3	SSW	4	54	65	75	0·10	4·4	pr_0 13h, r 17h–18h.
19	1017·8	NW	3	51	67	49	trace	8·3	pr_0 11h.
20	1017·7	NW	2	49	61	88	0·35	3·7	tlRr_0 11h–13h, t 15h.
21	1016·8	NE	5	53	68	56	0·05	3·5	r_0–r 9h–10h, pr_0 11h.
22	1016·0	NE	4	56	61	92	trace	0·8	id_0 13h–15h.
23	1011·3	NNE	2	53	59	85	0·09	0·0	R$r_0$5h, d_0 9h–10h.
24	1004·7	NNE	4	53	57	82	0·02	0·0	id_0 5h–7h, r_0 19h–20h.
25	1007·1	NNE	2	48	60	53	—	2·7	
26	1016·4	SW	2	48	65	56	trace	6·0	pr_0 16h.
27	1023·5	SSW	4	47	68	54	—	12·1	
28	1013·2	SW	4	57	63	88	trace	1·2	id_0 8h–13h. pr_0 14h.
29	1013·7	SSW	4	58	69	49	—	7·2	
30	1011·1	WSW	3	53	67	68	0·05	7·8	qpRr_0 11h, pr_0 17h & 18h.
*	1016·6	—		52	67	59	1·15	220·4	*Means or Totals.

General Rainfall for June 1939

	Per cent.
England and Wales	106
Scotland	82
Ireland	88
British Isles	96

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